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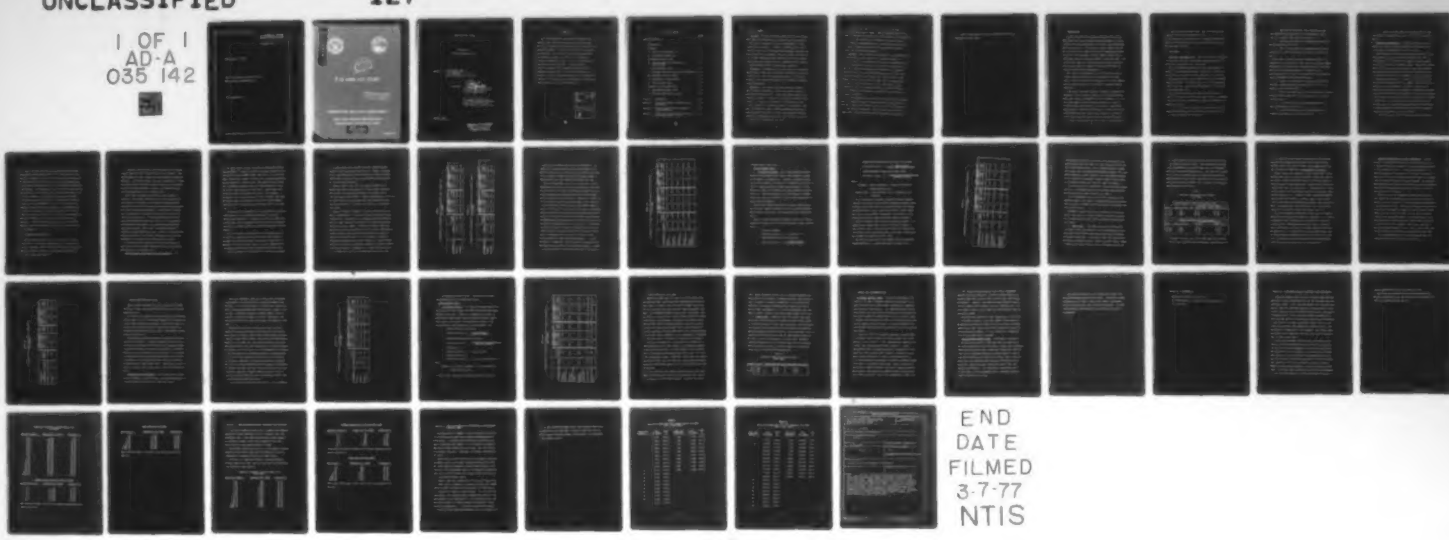

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FBM LOAD LIST STUDY

Navy Fleet Material Support Office
Mechanicsburg, Pennsylvania

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FBM LOAD LIST STUDY

OPERATIONS ANALYSIS DEPARTMENT

NAVY FLEET MATERIAL SUPPORT OFFICE

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Report 127

FBM LOAD LIST STUDY

REPORT 127

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ABSTRACT

This study evaluates alternative techniques for computing FBM (Fleet Ballistic Missile) tender load lists, given specified performance goals. Areas that are evaluated include: (1) the use of alternative demand distributions; (2) the use of alternative techniques for controlling range; (3) the use of alternative optimization models; and (4) the use of minimum item protection level constraints. Alternatives are evaluated separately for equipment-related and non-equipment-related items. The various techniques are evaluated using actual FBM demand data. The models are evaluated in terms of units effectiveness, requisitions effectiveness, and range effectiveness.

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EXECUTIVE SUMMARY

1. Problem. To meet the Fleet range goals for the AS 31 FBM (Fleet Ballistic Missile) tender load list produced in July 1975, a range criteria was implemented to add items to the load list. Further, to meet the cost constraints, high unit price items were manually reviewed and most high price, low demand items were eliminated from the load. These procedures were considered to be an interim solution and an in-depth review, evaluation, and redesign of the FBM tender load list model was initiated.

2. Objective. The objective of this study is to develop a computational model with sufficient flexibility to meet the Fleet's range, cost and performance goals. This study addresses only the basic FBM load list without the Weapon Systems Supplement.

3. Approach. This study evaluates possible changes to computational techniques in the current model, given a specified performance goal. Areas that were examined and evaluated include: (1) the use of alternative demand distributions; (2) the use of alternative techniques for controlling range; (3) the use of models that minimize units short, requisitions short, demand-weighted units short, demand-weighted requisitions short, and demand-weighted-essentiality-weighted units short; and (4) the use of constraints on the item protection level.

The AS 31 was used as the test ship for building and evaluating alternative loads. The alternative models were evaluated using two quarters of actual demands placed against the AS 31. The models were evaluated in terms of units effectiveness, requisitions effectiveness, and range effectiveness. Equipment-related and non-equipment-related items were evaluated separately.

4. Findings. For equipment-related items, a combined Normal-Poisson distribution was found to describe demand the most accurately. An optimization model was recommended for range determination in lieu of the current range criteria. The study shows that models that minimize either demand-weighted units short or demand-weighted requisitions short will produce similar loads and will outperform the other models tested. The study also shows that a minimum item protection level constraint of 50%, which would ensure stocking at least the average quarterly demand, produces little change in performance as compared to the current 1% minimum protection.

For non-equipment-related items, the Normal distribution and the combined Normal-Poisson distribution produced very similar results (both better than the Poisson distribution) for describing item demand. The study also shows that an optimization model that minimizes demand-weighted requisi-

tions short outperforms all other tested models for non-equipment-related items.

I. INTRODUCTION

During the July 1975 production cycle for the AS 31 FBM tender load list, problems were encountered in trying to meet the Fleet range goals and dollar value constraints for this load list. To obtain the range desired for the AS 31 load list, a range criteria was implemented whereby any item with a quarterly average demand greater than a specified range cut value was added to the load list. High unit priced items were then manually reviewed and many of the higher priced, low demand items were eliminated in order to meet the cost constraints.

The above was considered an interim solution and an in-depth review, evaluation, and redesign of the FBM tender load list model was initiated. This study addresses only the basic FBM load list without the Weapon Systems Supplement.

This study evaluates possible changes to computational techniques in the current model, given the effectiveness goals specified in OPNAVINST 4000.57D (reference 1). Areas that were examined and evaluated include: (1) the use of the Poisson distribution in the place of the Normal distribution to describe item demand; (2) the use of alternative techniques for controlling range; (3) the use of models that minimize demand-weighted requisitions short, units short, demand-weighted units short or demand-weighted-

essentiality-weighted units short; and (4) the use of constraints on the item protection level.

The purpose of this study is to develop a model with sufficient flexibility to meet the Fleet's range, cost, and performance goals.

II. APPROACH

A. LOAD LIST CANDIDATE FILE. The AS 31 load list candidate file used for the July 1975 production cycle was used to create the alternative test load lists.

The ER (Equipment-Related) and NER (Non-Equipment-Related) items will be discussed separately. An item is said to be an equipment-related item when it is on the ICP (Inventory Control Point) candidate file of Allowance Parts List items. An item is said to be a non-equipment-related item when it has historical demand but is not on the ICP candidate file.

There were 51,611 ER load list candidate items of which 7,570 (about 15%) had historical demand. Characteristics of the key data elements are shown in APPENDIX B and summarized below:

- 52% of the ER load list candidate items had a predicted average quarterly demand of .05 or less, i.e., less than one demand in five years.

. Only 8% of the ER load list candidate items had a predicted average quarterly demand greater than 1.00, i.e., greater than four units a year.

. 94% of the ER load list candidates had an average requisition size of one.

. 59% of the ER load list candidates had a unit price of $5 or less and 90% had a unit price of $100 or less.

There were 1,922 NER load list candidate items. In accordance with reference 2, NER items with a single demand frequency or a total two year demand quantity of less than four units were excluded from the candidate file. Characteristics of the key data elements for NER items are shown in APPENDIX C and summarized below:

. 46% of the NER load list candidate items had a predicted average quarterly demand of 2.0 or less, i.e., eight or less units per year.

. 11% of the NER load list candidates had a predicted average demand greater than 20 per quarter, i.e., over 80 units per year.

. 1% of the NER load list candidates had an average requisition size of one.

. 26% of the NER load list candidates had an average requisition size greater than ten.

. 71% of the NER load list candidates had a unit price of $5 or less and 98% had a unit price of $100 or less.

B. EVALUATION DEMAND DATA. Demands placed on the AS 31 during the third and fourth quarters of 1975 were used to evaluate the alternative test load lists.

The alternative test load lists were evaluated by range effectiveness, requisitions effectiveness, and units effectiveness. For this study, effectiveness was based only on FMSO load list candidate items. Range effectiveness refers to the number of AS 31 tender load list candidate NIINs demanded and satisfied divided by the number of AS 31 candidate NIINs that were demanded. A NIIN is said to be satisfied when there is at least one unit of the item on the tender regardless of the number of units of the item demanded during the quarter. Likewise, requisitions effectiveness refers to the number of requisitions demanded and satisfied divided by the number of requisitions demanded. A requisition is said to be satisfied when there are enough units of the item available to at least partially fill the requisition. Units effectiveness refers to the number of units demanded and satisfied by the load list quantity divided by the number of units demanded.

During the period used to evaluate the alternative test

load lists, the AS 31 was stationed at Charleston and was supporting some submarines other than those the load list was built to support. Thus, the effectiveness measures for the alternative test load lists are a relative comparison of alternative models rather than a true measure of deployed effectiveness. The demand tape for the AS 31 tender for the third quarter of 1975 contained 2,192 NIINs that were not on the AS 31 candidate list and were, therefore, excluded from the effectiveness statistics. These NIINs accounted for 45% of the NIINs demanded, 32% of the requisitions demanded, and 29% of the units demanded. The demand tape for the AS 31 tender for the fourth quarter of 1975 contained 2,097 NIINs that were not on the AS 31 candidate list and were, therefore, not counted in the effectiveness statistics. These NIINs accounted for 41% of the NIINs demanded, 30% of the requisitions demanded, and 28% of the units demanded.

III. EQUIPMENT-RELATED ITEMS

As previously defined, an item is said to be an ER item when it is on the ICP candidate file. The AS 31 ER load list candidate items include both items with historical demand and items installed on the supported submarines but with no historical demand.

Currently, the goals for the ER portion of the AS(FBM) tender load list are a range of about 25,000 items, a net effectiveness of 95%, and as high a gross effectiveness as possible. The current model utilizes a range cut to achieve the desired range and then computes depth using a variable protection model designed to satisfy a demand-weighted units effectiveness goal at minimum cost.

This study evaluates alternative range and depth criteria. The Normal distribution will be compared with the Poisson distribution and a combined Normal-Poisson distribution to see which distribution describes the demand of the ER items most accurately. Various range criteria will be compared to see which one will give the desired range most efficiently. An effectiveness goal based on predicted demand-weighted units short will be compared to effectiveness goals based on predicted demand-weighted requisitions short, units short, and demand-weighted-essentiality-weighted units short. Finally, a minimum item protection level of 1%, which is currently used, will be compared to a minimum item protection level of 50%.

It should be noted that all statistics presented in this section reflect model computations and do not reflect application of any constraints.

A. <u>RANGE CRITERIA AND PROBABILITY DISTRIBUTIONS</u>. The

current model uses a range cut based on predicted quarterly average demand in order to obtain the range desired for the ER portion of the AS(FBM) tender load list. For the AS 31 tender load list a range cut based on a predicted quarterly average demand of .05 was used. This means that any load list candidate item which had one demand predicted every five years was added to the load list. Other range cuts have been used on other FBM load lists. For example, a range cut of .10 was used for the AS 32 tender load list. This means that any candidate item which had one demand predicted every two and a half years was added to the load list.

An alternative technique used for obtaining the desired range makes use of an optimization model to maximize effectiveness subject to a range goal or dollar value goal. By definition this technique should be more cost effective than using a range cut based on predicted quarterly average demand.

For all the test loads created in this segment of the ER study, an effectiveness goal that minimizes demand-weighted units short was used along with a range goal of between 25,000 and 27,000 items. Since the comparison of the range cut model and the optimization model may vary significantly based on the probability distribution assump-

tion, both models were tested with both the Normal distribution and the Poisson distribution. TABLE I compares the two probability distributions for the range cut model, while TABLE II compares the two probability distributions for the optimization model.

TABLE I shows that, for the range cut model, the Normal distribution had about 20% better units effectiveness, about 9% better requisitions effectiveness, and the same range effectiveness. Range effectiveness is the same for both distributions because the items carried in both runs were identical. A range cut value of .05 was used in both cases.

TABLE II, again, compares a load list built using the Normal distribution to a load list built using the Poisson distribution. However, in this comparison the optimization model is used instead of the range cut based on predicted quarterly average demand. The load list built using the Normal distribution had about 20% better units effectiveness, slightly higher requisitions effectiveness, and about 7% lower range effectiveness. For this model, the Normal distribution appears to be more accurate in regard to depth although the Poisson distribution appears to be more accurate in selecting range. Consequently, it was decided to build a test load list using the optimization model and a com-

TABLE I

COMPARISON OF PROBABILITY DISTRIBUTIONS WITH A RANGE CUT
(ER ITEMS)

ALTERNATIVE	RANGE	DOLLAR VALUE	THIRD QUARTER 1975 GROSS UNITS EFF	THIRD QUARTER 1975 GROSS REQNS EFF	THIRD QUARTER 1975 RANGE EFF	FOURTH QUARTER 1975 GROSS UNITS EFF	FOURTH QUARTER 1975 GROSS REQNS EFF	FOURTH QUARTER 1975 RANGE EFF
NORMAL	25,313	3.56M	64.9%	79.0%	90.8%	71.6%	84.8%	93.9%
POISSON	25,313	3.06M	44.0%	70.1%	90.8%	50.1%	76.4%	93.9%

TABLE II

COMPARISON OF PROBABILITY DISTRIBUTIONS WITH AN OPTIMIZED RANGE
(ER ITEMS)

ALTERNATIVE	RANGE	DOLLAR VALUE	THIRD QUARTER 1975 GROSS UNITS EFF	THIRD QUARTER 1975 GROSS REQNS EFF	THIRD QUARTER 1975 RANGE EFF	FOURTH QUARTER 1975 GROSS UNITS EFF	FOURTH QUARTER 1975 GROSS REQNS EFF	FOURTH QUARTER 1975 RANGE EFF
NORMAL	26,775	1.09M	65.1%	73.3%	80.2%	70.9%	77.4%	81.2%
POISSON	25,908	1.23M	45.5%	71.7%	87.4%	51.4%	77.4%	88.8%

bination of the Normal and Poisson distributions. For items with a predicted quarterly average demand less than or equal to one, the Poisson distribution was used. For items with a predicted quarterly average demand greater than one, the Normal distribution was used.

TABLE III compares this new test load list to the performances of the four load lists previously mentioned. The load list built using the Normal distribution with a range cut based on predicted quarterly average demand had the overall best performance. However, the load lists built using the range cut are extremely costly relative to the load lists built using the optimization model to control the range. The load list built using the combined Normal-Poisson distribution and the optimization model to control the range had about the same units effectiveness and requisitions effectiveness as the load list built using the Normal distribution with the range cut. In addition, this load list built using the Normal-Poisson distribution cost about one-half as much as the load list built using the Normal distribution with a range cut and had only about 4% lower range effectiveness. It is, therefore, recommended that the combined Normal-Poisson distribution along with the optimization model to control the range be used for future computations of ER items on

TABLE III

COMPARISON OF RANGE CRITERIA AND PROBABILITY DISTRIBUTIONS
(ER ITEMS)

ALTERNATIVE	RANGE	DOLLAR VALUE	THIRD QUARTER 1975			FOURTH QUARTER 1975		
			GROSS UNITS EFF	GROSS REQNS EFF	RANGE EFF	GROSS UNITS EFF	GROSS REQNS EFF	RANGE EFF
Normal - Range Cut	25,313	3.56M	64.9%	79.0%	90.8%	71.6%	84.8%	93.9%
Poisson - Range Cut	25,313	3.06M	44.0%	70.1%	90.8%	50.1%	76.4%	93.9%
Normal - Optimization	26,775	1.09M	65.1%	73.3%	80.2%	70.9%	77.4%	81.2%
Poisson - Optimization	25,908	1.23M	45.5%	71.7%	87.4%	51.4%	77.4%	88.8%
Normal/ Poisson - Optimization	25,907	1.86M	65.5%	78.4%	87.4%	71.7%	83.1%	88.8%

AS(FBM) tender load lists.

B. EFFECTIVENESS GOALS.

1. Optimization Model. The current model minimizes essentiality-weighted units short, where demand is used as a measure of essentiality. Demand is frequently used in load list models as a measure of essentiality, due to the lack of a more meaningful essentiality measure. In the FBM area, there is an FBM MEC (Military Essentiality Code) which is a relative measure of item importance. However, there is a very low confidence level in the accuracy of the current MEC assignments.

This study compares optimization models that minimize units short, demand-weighted units short, demand-weighted-MEC-weighted units short, and demand-weighted requisitions short.

Each of these optimization models results in a slightly different computation of the item protection level, as shown below:

- Units Short Model

  $$\text{Protection Level} = 1 - \lambda\ (\text{Unit Price})$$

- Demand-Weighted Units Short Model

  $$\text{Protection Level} = 1 - \frac{\lambda\ (\text{Unit Price})}{\text{Quarterly Demand}}$$

- Demand-Weighted-MEC-Weighted Units Short Model

$$\text{Protection Level} = 1 - \frac{\lambda \text{ (Unit Price)}}{\text{(Qtrly Dmd)(Essentiality)}}$$

- Demand-Weighted Requisitions Short Model

$$\text{Protection Level} = 1 - \frac{\lambda \text{ (Unit Price)(Avg Reqn Size)}}{\text{Quarterly Demand}}$$

where

λ (lambda) = control parameter to achieve specified effectiveness value

Essentiality = value between 0 and 1.0 based on the FBM MEC

It is noted that the model minimizing average demand - weighted units short and the model minimizing average demand - weighted requisitions short are identical when the average requisition size is one. Since about 94% of the ER candidate items had an average requisition size of one, little difference should be expected between these two models.

TABLE IV compares the various optimization models. The lambda value in each case was set to produce a range of about 27,000 items. Due to the relatively low cost of the load based on the units short model, the range of that model was allowed to exceed the 27,000 limit.

The load list built using the model minimizing average demand-weighted units short had about 5% better units

TABLE IV

COMPARISON OF OPTIMIZATION MODELS WITH NORMAL DISTRIBUTION
(ER ITEMS)

			THIRD QUARTER 1975			FOURTH QUARTER 1975		
ALTERNATIVE	RANGE	DOLLAR VALUE	GROSS UNITS EFF	GROSS REQNS EFF	RANGE EFF	GROSS UNITS EFF	GROSS REQNS EFF	RANGE EFF
Units Short	31,276	.40M	60.5%	62.8%	69.0%	64.4%	65.6%	69.6%
Dmd-Weighted Units Short	26,775	1.09M	65.1%	73.3%	80.2%	70.9%	77.4%	81.2%
Dmd-Weighted Requisitions Short	26,614	1.04M	64.6%	72.0%	78.8%	70.2%	75.6%	79.3%
Demand/MEC-Weighted Units Short	26,709	.99M	64.9%	72.3%	78.2%	70.5%	75.3%	78.7%

effectiveness and about 11% better requisitions and range effectiveness than the load list that minimized units short. The demand-weighted units short, demand-weighted requisitions short and the demand-weighted-MEC-weighted units short models produced similar results, with the demand-weighted units short model providing slightly higher effectiveness at a slightly higher cost than the other two models.

Due to the lack of confidence in the current MEC assignments, it is recommended that the average demand-weighted-MEC-weighted units short model not be used.

It is recommended that a model that minimizes either demand-weighted units short or demand-weighted requisitions short be used to compute the ER portion of the AS(FBM) load list in the future.

APPENDIX D shows the load list quantities that would result from using the combined Normal-Poisson distribution and the optimization model that minimizes demand-weighted units short.

2. Model Goals. The goals specified in reference 1 for tender load lists require 95% net effectiveness and as high gross effectiveness as possible considering funding and space constraints. For recent loads, SSPO has further specified a desired range of 25,000 to 27,000 items. TABLE V compares the range, dollar value, and predicted net and

gross effectiveness values resulting from various settings of the lambda parameter value. The statistics are based on the recommended optimization model with the combined Normal-Poisson demand distribution. The first set of simulation statistics results from the model that minimizes demand-weighted requisitions short, while the second set of simulation statistics results from the model that minimizes demand-weighted units short.

TABLE V

SIMULATION PREDICTED EFFECTIVENESS
(ER ITEMS)

DEMAND-WEIGHTED REQUISITIONS SHORT MODEL			
		PREDICTED EFFECTIVENESS	
RANGE	DOLLAR VALUE	NET REQUISITION	GROSS REQUISITION
9,978	.64M	97.5%	84.0%
17,122	1.09M	98.8%	91.9%
25,868	1.82M	99.2%	96.4%

DEMAND-WEIGHTED UNITS SHORT MODEL			
		PREDICTED EFFECTIVENESS	
RANGE	DOLLAR VALUE	NET UNIT	GROSS UNIT
15,414	1.01M	95.8%	91.2%
21,908	1.49M	96.2%	93.8%
25,907	1.86M	96.3%	94.7%

Although the load list with 25,868 items built using the model that minimizes demand-weighted requisitions short

and the load list with 25,907 items built using the model that minimizes demand-weighted units short have quite different predicted effectiveness, their actual effectiveness as shown in TABLE IV is approximately the same.

TABLE V shows one problem of using a predicted 95% net effectiveness goal to build an AS(FBM) tender load list for ER items. Using the demand-weighted units short model, a range of about 15,000 items gives a predicted net effectiveness greater than the desired goal. Increasing the range by 10,000 items to get the desired range only increases the net effectiveness by .5%. Likewise, using the demand-weighted requisitions short model, a range of about 10,000 items gives a predicted net effectiveness greater than the desired goal. Increasing the range by 16,000 to get the desired range only increases the net effectiveness by 1.7%.

If the recommended optimization model with the combined Normal-Poisson demand distribution is approved, it is further recommended that the model goals be stated in terms of a minimum 95% net effectiveness and that either a desired range, desired dollar value, or desired gross effectiveness be specified. It is noted that a gross effectiveness goal of 95% provided the desired range for the test load. However, it should not be concluded that this effectiveness goal would give the same range for other loads.

C. MINIMUM ITEM PROTECTION LEVEL CONSTRAINT. In this section, a minimum item protection level constraint of 1%, as currently used, is compared to a minimum item protection level constraint of 50%. A minimum item protection level constraint of 50% means that any item that makes the load list will have a load list quantity equal to or greater than its predicted quarterly average demand. The combined Normal-Poisson distribution along with the optimization model which minimizes demand-weighted units short was used for this portion of the study.

TABLE VI shows the comparison between the load list built using the minimum item protection level constraint of 1% and the load list built using the minimum item protection level constraint of 50%. Raising the minimum item protection level to 50% increased the range by only 18 items and the dollar value by $70,000. Also, the two load lists had virtually the same performance. The reason there is not much difference between these two load lists is that about 92% of the load list candidate items have a predicted quarterly average demand of one or less. These items could not get less than 50% protection and make the load list.

It is recommended that the present minimum item protection level constraint of 1% be continued.

TABLE VI

MINIMUM ITEM PROTECTION LEVEL COMPARISON
(ER ITEMS)

PROTECTION LEVEL ALTERNATIVE	RANGE	DOLLAR VALUE	THIRD QUARTER 1975			FOURTH QUARTER 1975		
			GROSS UNITS EFF	GROSS REQNS EFF	RANGE EFF	GROSS UNITS EFF	GROSS REQNS EFF	RANGE EFF
Minimum of 1%	25,907	1.86M	65.5%	78.4%	87.4%	71.7%	83.1%	88.8%
Minimum of 50%	25,925	1.93M	65.5%	78.6%	87.6%	71.7%	83.2%	89.0%

IV. NON-EQUIPMENT-RELATED ITEMS

As previously defined, an item is said to be an NER item when it has historical demand but is not on the ICP candidate file.

Currently, the goals for the NER portion of the AS(FBM) tender load list are a net effectiveness of 95% and as high a gross effectiveness as possible. The current model computes range and depth using an optimization model that minimizes demand-weighted units short and assumes a Normal demand distribution.

This study evaluates alternative demand distributions and optimization models. The Normal distribution will be compared with the Poisson distribution and a combined Normal-Poisson distribution to see which distribution describes the demand of the NER items the most accurately. An optimization model based on predicted demand-weighted units short will be compared to an optimization model based on predicted demand-weighted requisitions short. These will also be compared to models that minimize units short and requisitions short.

A. PROBABILITY DISTRIBUTIONS. For the test loads created in this segment of the NER study, an optimization model that minimizes demand-weighted units short was used.

TABLE VII compares a load list built using the Normal distribution to a load list built using the Poisson distribution. As in the ER study, a load list was also built using a combined Normal-Poisson distribution. Again, if an item had a predicted quarterly average demand of one or less the Poisson distribution was used. Otherwise, the Normal distribution was used to describe the demand for the item.

TABLE VII shows that the load list built using the Normal distribution had about 30% better units effectiveness, about 14% better requisitions effectiveness and about 2% better range effectiveness than the Poisson distribution. TABLE VII also shows that the Normal distribution and the combined Normal-Poisson had essentially the same performance. The reason for this is that: (1) in accordance with reference 2, all NER items with a predicted quarterly average demand of .5 or less were deleted from the load list candidate file unless a mandatory or minimum override was assigned; and (2) the Poisson distribution and the Normal distribution will assign the same load list quantity for most items with a predicted quarterly average demand between .5 and 1.0 using the control parameter for item protection level used to build these two NER load lists.

To be consistent with the ER criteria, it is recommended

TABLE VII

COMPARISON OF NORMAL AND POISSON PROBABILITY DISTRIBUTION
(NER ITEMS)

ALTERNATIVE	RANGE	DOLLAR VALUE	THIRD QUARTER 1975			FOURTH QUARTER 1975		
			GROSS UNITS EFF	GROSS REQNS EFF	RANGE EFF	GROSS UNITS EFF	GROSS REQNS EFF	RANGE EFF
Normal	815	73K	64.0%	38.8%	47.6%	62.0%	38.3%	46.4%
Poisson	783	61K	30.6%	24.8%	45.2%	35.2%	25.5%	44.4%
Normal-Poisson	807	73K	64.0%	38.6%	47.2%	61.9%	38.1%	46.1%

that this combined Normal-Poisson distribution be used for future computations on AS(FBM) NER items.

B. EFFECTIVENESS GOALS.

1. Optimization Model. The current AS(FBM) tender load list model uses an optimization model which minimizes demand-weighted units short. TABLE VIII compares this model to optimization models which minimize demand-weighted requisitions short, units short, and requisitions short. The item protection level equations for these models are:

- Demand-Weighted Units Short

$$\text{Protection Level} = 1 - \frac{\lambda \text{ (Unit Price)}}{\text{Quarterly Demand}}$$

- Demand-Weighted Requisitions Short

$$\text{Protection Level} = 1 - \frac{\lambda \text{ (Unit Price)(Avg Reqn Size)}}{\text{Quarterly Demand}}$$

- Units Short

$$\text{Protection Level} = 1 - \lambda \text{ (Unit Price)}$$

- Requisitions Short

$$\text{Protection Level} = 1 - \lambda \text{ (Unit Price)(Avg Reqn Size)}$$

where

λ (lambda) is a control parameter to achieve specified effectiveness value

For this study, the Normal distribution along with a 95%

TABLE VIII

COMPARISON OF OPTIMIZATION MODELS WITH NORMAL DISTRIBUTION
(NER ITEMS)

ALTERNATIVE	RANGE	DOLLAR VALUE	THIRD QUARTER 1975			FOURTH QUARTER 1975		
			GROSS UNITS EFF	GROSS REQNS EFF	RANGE EFF	GROSS UNITS EFF	GROSS REQNS EFF	RANGE EFF
Demand-Weighted Units Short	815	73K	64.0%	38.8%	47.6%	62.0%	38.3%	46.4%
Demand-Weighted Requisitions Short	1,777	142K	70.6%	70.2%	92.7%	69.7%	69.8%	93.7%
Demand-Weighted Units Short (Lg Range)	1,649	236K	70.3%	66.1%	87.6%	69.4%	65.6%	87.4%
Units Short	1,458	42K	65.1%	53.3%	78.9%	63.1%	51.8%	78.4%
Requisitions Short	1,789	72K	61.8%	67.5%	93.2%	60.4%	66.4%	93.6%

net effectiveness goal was used.

TABLE VIII shows that the load list built using the optimization model that minimizes demand-weighted requisitions short had about twice the range at about twice the cost of the load list that minimizes demand-weighted units short. The demand-weighted requisitions short model also had about a 7% better units effectiveness, about 31% better requisitions effectiveness, and about a 46% better range effectiveness than the demand-weighted units short model. Although the optimization model that minimizes demand-weighted requisitions short costs more, this cost difference is relatively small compared to the investment in equipment-related items and is offset by its superior performance.

Due to the differences in range and cost between the demand-weighted units short model and the demand-weighted requisitions short model, it was decided to build another load list minimizing demand-weighted units short but with a more comparable range. TABLE VIII shows that this load list costs $94,000 more than the load list that minimized demand-weighted requisitions short but still did not have as good performance.

It is noted that the demand-weighted requisitions short model performed better than the requisitions short model, particularly in units effectiveness. However, the units

short model performed better than the demand-weighted units short model, particularly in requisitions and range effectiveness. Overall, as shown in TABLE VIII, the optimization model which minimizes demand-weighted requisitions short had the best performance. It is thus recommended that this model be used to build future NER AS(FBM) tender load lists.

2. Model Goals. TABLE IX shows the range, cost, predicted net effectiveness, and predicted gross effectiveness for the NER portion of three load lists built using the Normal distribution and an optimization model based on minimizing demand-weighted requisitions short. This table shows that the problem encountered with the 95% net effectiveness goal for ER items is not as significant for NER items. However, since theoretically 95% net effectiveness could be achieved while stocking one item, it would be better to establish a range, cost, or gross effectiveness goal.

TABLE IX

SIMULATION PREDICTED EFFECTIVENESS
(NER ITEMS)

RANGE	COST	PREDICTED NET EFF	PREDICTED GROSS EFF
774	20K	82.9%	49.3%
1,502	71K	92.7%	80.7%
1,777	143K	95.7%	91.8%

V. SUMMARY AND RECOMMENDATIONS

A. EQUIPMENT-RELATED ITEMS. Currently, the Normal distribution is used to describe demand for ER items. The study evaluated use of the Normal, Poisson and a combined Normal-Poisson distribution. The combined Normal-Poisson distribution uses the Poisson distribution for items with a predicted quarterly average demand of one or less and uses the Normal distribution for items with a predicted quarterly average demand greater than one. It was recommended that the combined Normal-Poisson distribution be used to describe item demand.

A range cut based on predicted quarterly average demand is now being used to obtain the desired range for the ER portion of the load list. This technique was compared with a model that optimizes both range and depth. It was recommended that an optimization model be adopted for both range and depth computations, based on a specified range goal, dollar value goal, or gross effectiveness goal.

An effectiveness goal based on minimizing demand-weighted units short is currently being used. Models minimizing units short, demand-weighted units short, demand-weighted-MEC-weighted units short and demand-weighted requisitions short were evaluated. This study recommended a model that

minimizes either demand-weighted units short or demand-weighted requisitions short. Either of these models will produce loads with similar range, dollar value, and actual performance. However, the predicted effectiveness statistics for these similar loads are quite different, with the units model having a lower predicted effectiveness than the requisition model.

A minimum item protection level constraint of 1% is used in the current program. The study showed little change in performance between this model and the one using a minimum constraint of 50%, which would ensure stocking at least the average quarterly demand. It was, therefore, recommended that the 1% constraint be retained.

B. NON-EQUIPMENT-RELATED ITEMS. The Normal distribution is currently being used to describe demand for NER items. The study evaluated use of the Normal, Poisson, and a combined Normal-Poisson distribution, where the Poisson was used for items with a predicted quarterly average demand of one or less and the Normal was used for all other items. Both the Normal and the combined Normal-Poisson distributions produced very similar results, which were better than the Poisson distribution. For the sake of consistency with the ER items, it was recommended that a combined Poisson-Normal distribution be used.

The current NER model is an optimization model that minimizes demand-weighted units short. Alternative models minimizing units short, requisitions short, and demand-weighted requisitions short were also evaluated. A model that minimizes demand-weighted requisitions short was recommended.

APPENDIX A: REFERENCES

1. OPNAVINST 4000.57D of 4 Dec 1975

2. Joint NAVSUP/SSPO ltr NAVSUP 0341B SSPO 206/146 of 3 Feb 1975

APPENDIX B: EQUIPMENT-RELATED CANDIDATE ITEM STATISTICS

A two year demand base was used to compute the predicted quarterly average item demand for the AS 31 tender load list candidate items. If an item had demand within this two year period, then the predicted quarterly average demand for the item is equal to the total demand during the two year period divided by eight. If an item did not have demand within this two year period, its predicted quarterly average demand is set equal to the best replacement factor for the item times the supported item population divided by four. The population is comprised of two elements: that which can be installed by the requestor and that which can be installed only at the tender level.

If an item had demand within the two year demand base period, then the average requisition size for the item is set equal to the total demands during the two year period divided by the total frequencies of demand during the two year period. If an item did not have demand during this two year period, its average requisition size is set equal to one, unless the item had a predicted quarterly average demand of zero and no mandatory or minimum technical override. If an item had a predicted quarterly average demand of zero and no mandatory or minimum technical override, its

average requisition size is set equal to zero.

Statistics on predicted quarterly average demands, average requisition size, and unit price for the AS 31 ER load list candidate items follow:

PREDICTED QUARTERLY AVERAGE DEMAND FOR ER ITEMS

PREDICTED DEMAND ≤	CUMULATIVE NR ITEMS	CUMULATIVE %
0.00	4,591	8.90
0.05	26,992	52.30
0.10	32,016	62.03
0.20	38,450	74.50
0.30	41,510	80.43
0.40	43,238	83.78
0.50	44,498	86.22
1.00	47,294	91.64
1.50	48,567	94.10
2.00	49,193	95.32
3.00	49,891	96.67
4.00	50,274	97.41
5.00	50,508	97.86
10.00	51,047	98.91
20.00	51,335	99.47
30.00	51,425	99.64
40.00	51,477	99.74
50.00	51,499	99.78
100.00	51,553	99.89
1000.00	51,607	99.99
10000.00	51,610	100.00

AVERAGE REQUISITION SIZE FOR ER ITEMS

REQUISITION SIZE ≤	CUMULATIVE NR ITEMS	CUMULATIVE %
0.0	1	0.00
1.0	48,393	93.76
1.5	48,753	94.46
2.0	49,511	95.93
3.0	50,022	96.92
4.0	50,373	97.60
5.0	50,623	98.09
10.0	51,148	99.10

There were 463 items (.9%) with an average requisition size greater than 10.0.

UNIT PRICE FOR ER ITEMS

UNIT PRICE ≤	CUMULATIVE NR ITEMS	CUMULATIVE %
$ .25	7,647	14.82
.50	11,806	22.87
1.00	17,383	33.68
5.00	30,310	58.73
10.00	35,193	68.19
100.00	46,240	89.59
1000.00	50,660	98.16
10000.00	51,559	99.90

There were 52 items (.1%) with a unit price greater than $10,000.

APPENDIX C: NON-EQUIPMENT-RELATED CANDIDATE ITEM STATISTICS

A two year demand base was used to compute the predicted quarterly average demand for the AS 31 tender load list candidate items. The predicted quarterly average demand for an item is equal to the total demand for the item during the two year period divided by eight.

The average requisition size of an item equals the total demands during the two year period divided by the total frequencies of demand during the two year period.

Statistics on predicted quarterly average demands, average requisition size, and unit price for AS 31 NER load list candidate items follow:

PREDICTED QUARTERLY AVERAGE DEMAND FOR
NER ITEMS

PREDICTED DEMAND ≤	CUMULATIVE NR ITEMS	CUMULATIVE %
1.00	419	21.80
1.50	692	36.00
2.00	878	45.68
2.50	1,008	52.44
3.00	1,099	57.18
4.00	1,215	63.22
5.00	1,318	68.57
10.00	1,549	80.59
20.00	1,706	88.76
30.00	1,763	91.73
40.00	1,793	93.29
50.00	1,818	94.59
100.00	1,868	97.19
1000.00	1,920	99.90
10000.00	1,922	100.00

AVERAGE REQUISITION SIZE FOR NER ITEMS

REQUISITION SIZE ≤	CUMULATIVE NR ITEMS	CUMULATIVE %
1.0	18	.94
1.5	147	7.65
2.0	369	19.20
3.0	694	36.11
4.0	909	47.29
5.0	1,050	54.63
10.0	1,415	73.62

There were 507 items(26.38%)with an average requisition size greater than 10.0.

UNIT PRICE FOR NER ITEMS

UNIT PRICE ≤	CUMULATIVE NR ITEMS	CUMULATIVE %
$ .25	269	14.00
.50	486	25.29
1.00	800	41.63
5.00	1,374	71.49
10.00	1,546	80.44
100.00	1,874	97.50
1000.00	1,915	99.63
10000.00	1,919	99.84

There were three items (.16%) with a unit price greater than $10,000.

APPENDIX D: LOAD LIST QUANTITY DISTRIBUTION FOR EQUIPMENT-RELATED ITEMS

The quantities in TABLES I and II are based on the use of an optimization model that minimizes demand-weighted units short. A combined Normal-Poisson distribution was used to describe item demand. If an item had a predicted quarterly average demand of one or less, then the Poisson distribution was used. Otherwise, the Normal distribution was used.

About 85% of the AS 31 ER load list candidate items had no demand within the two year demand base period and thus had their predicted quarterly average demand based on the item BRF (Best Replacement Factor) and supported population. About 81% of the ER items that actually made the load list were these BRF forecast items.

TABLE I shows the distribution of load list quantities for items where the quantity is based on historical demand. TABLE II shows the quantity distribution for items where the quantity is based on a BRF forecast. It is noted that these quantities represent model computations prior to the application of any constraints. In a production mode, the quantities based on a BRF forecast are subjected to the following constraints: (1) maximum allowed depth equals 50 unless the MRU (Minimum Replacement Unit) is greater than

50; (2) the maximum extended dollar value equals $100 unless the dollar value of the MRU is greater than $100; and (3) if both above conditions apply, the quantity is constrained to the smaller value.

TABLE I

LOAD LIST QUANTITIES FOR "DEMAND BASED" ER ITEMS
(AS 31 TEST LOAD)

LOAD LIST QUANTITY ≤	CUM. NR ITEMS	CUM. %
1	1,096	22.42
2	1,986	40.63
3	2,554	52.25
4	2,889	59.10
5	2,986	61.09
6	3,083	63.07
7	3,175	64.95
8	3,270	66.90
9	3,406	69.68
10	3,570	73.04
15	3,858	78.93
20	4,116	84.21
30	4,326	88.50
40	4,502	92.10
50	4,624	94.60
60	4,669	95.52
70	4,698	96.11
80	4,719	96.54
90	4,733	96.83

LOAD LIST QUANTITY ≤	CUM NR ITEMS	CUM. %
100	4,751	97.20
200	4,825	98.71
300	4,845	99.12
400	4,859	99.41
500	4,862	99.47
1000	4,878	99.80
2000	4,884	99.92
3000	4,886	99.96
4000	4,887	99.98
5000	4,888	100.00

TABLE II

LOAD LIST QUANTITIES FOR "BRF FORECAST" ER ITEMS
(AS 31 TEST LOAD)

LOAD LIST QUANTITY ≤	CUM. NR ITEMS	CUM. %	LOAD LIST QUANTITY ≤	CUM NR ITEMS	CUM. %
1	6,114	29.09	100	20,898	99.42
2	10,762	51.20	200	20,962	99.73
3	12,997	61.83	300	20,980	99.81
4	14,290	67.99	400	20,992	99.87
5	14,916	70.96	500	20,997	99.90
6	15,769	75.02	1,000	21,007	99.94
7	16,201	77.08	2,000	21,013	99.97
8	16,725	79.57	3,000	21,018	100.00
9	17,355	82.57	4,000	21,018	100.00
10	17,989	85.58	5,000	21,018	100.00
15	18,759	89.25	10,000	21,019	100.00
20	19,416	92.37			
30	19,808	94.24			
40	20,270	96.44			
50	20,637	98.18			
60	20,685	98.41			
70	20,716	98.56			
80	20,753	98.73			
90	20,781	98.87			

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13. ABSTRACT

This study evaluates alternative techniques for computing FBM (Fleet Ballistic Missile) tender load lists, given specified performance goals. Areas that are evaluated include: (1) the use of alternative demand distributions; (2) the use of alternative techniques for controlling range; (3) the use of alternative optimization models; and (4) the use of minimum item protection level constraints. Alternatives are evaluated separately for equipment-related and non-equipment-related items. The various techniques are evaluated using actual FBM demand data. The models are evaluated in terms of units effectiveness, requisitions effectiveness and range effectiveness.